Using Geographic Information System in Analyzing Hospital Accessibility: A Case Study in New Orleans

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ABSTRACT

This paper examines the use of Geographic Information System (GIS) methods to analyze the special accessibility to primary healthcare /hospitals in New Orleans. Census data at the census track level were used to define the population distribution (demand) and the related socioeconomic attributes, as well as the hospital distribution (supply) at the zip code level. The first part of the paper examined potential population in the catchment area using simple GIS overlay analysis based on circular buffers around each hospital by creating concentric rings of 1000, 1500 and 2000 meters around the hospitals. Different scores ranging from 1 to 4 were assigned to each concentric ring with 4 being the highest/closest score and 1 being the lowest/furthest one. The second part of the paper examined the possible inequality among different ethnic minorities and income subgroups using Spatial Cluster Analysis (SCA) tools in GIS.

Basic statistics were summarized for the entire population (White and three major ethnic minorities (Black, Asian and Hispanic)) with various accessibility scores. Generally, it was found that that hospital accessibility is very poor in New Orleans for the entire population with a weighted average access score of 1.81.

KEYWORDS: Accessibility, Healthcare accessibility, Geographic Information System (GIS).

INTRODUCTION

Healthcare is one of the most important issues in the United States and healthcare accessibility is a vital concern in many societies. The United States spend more than thirteen percent, one billion dollar a year, of the Gross Domestic Product (GDP) on healthcare (Rosenbaum et al., 1998). Since 1946, federal grants have been provided to advance healthcare services and ensure equal treatment without discrimination based on “race, color, origin or any other ground unrelated to the individual’s need for the service or the availability of the needed service in the facility” (U.S. Department of Health and Human Services, 2007).

Physical accessibility is the measure of the capacity of a location to be reached by, or to reach different locations (Rodrigue et al., 2009). Physical accessibility to healthcare in a given location is influenced by many factors, including the spatial distribution of healthcare (supply) and that of population (demand), the availability of socio-economic and financial resources and the geographic impedance, distance or time, between population and healthcare services (Aday and Andersen, 1974). The basic factor involved in the issue of healthcare access is the spatial distribution of healthcare (supply) and population (demand). If the distribution of healthcare and that of population do not match, access to healthcare would not be connected in space and access problems would exist (COGME, 2000).

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The development of GIS technology makes it possible to identify distributions of healthcare and population at a finer spatial resolution using disaggregated population data, detailed road network and the healthcare locations. There is a large volume of literature related to the use of GIS for measuring physical accessibility to healthcare. A number of publications review the various methods used (Wilknson et al., 1998; Albert et al., 2000; Cromley and McLafferty, 2002; Luo et al., 2003; Wang, 2012) and many publications review the application of these methods to different healthcare (Abdulkader, 2004; Guagliardo, 2004; Luo, 2004).

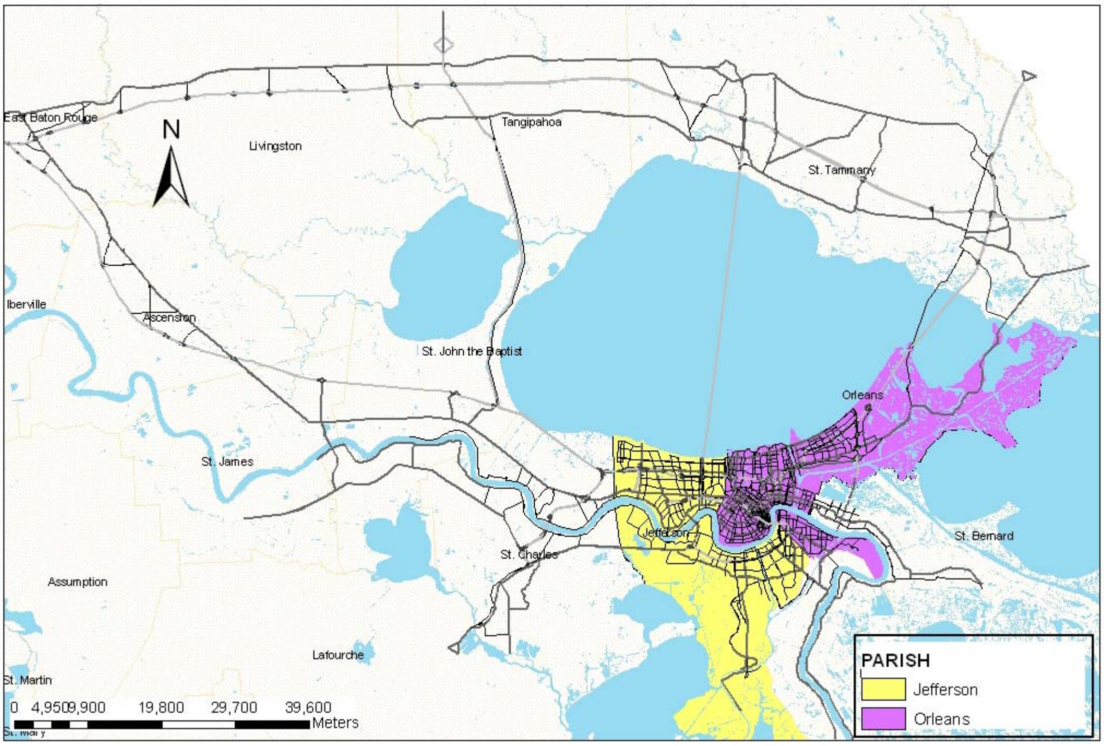

Figure 1: Study Area

The first part of this paper focuses primarily on measuring potential physical spatial accessibility to primary healthcare/hospitals in New Orleans, Orleans Parish in 2010, using simple GIS overlay analysis based on circular buffers around each hospital. The second part of the paper examines the possible inequality among different disadvantaged population subgroups (low income and minority residents) using Spatial Cluster Analysis (SCA) tools of hospital accessibility. Results may be used to help the US Department of Health and Human Services (DHHS) and state health departments design a better system for designation of areas of physician shortage.

The paper's main contribution is that the method applied to measuring hospital accessibility using smaller geographic units (that is; population at census tract level and hospitals at zip code level), and therefore more details of accessibility variations can be revealed.

Study Area and Data Sources

Figure 1 shows the regional area including the study area. The area is located in southeastern Louisiana. It includes seven-parishes. Orleans Parish was selected as the study area for this research because it is ranked as New Orleans most populous parish. The population data were extracted from the 2000 Census Summary File 1 (US Bureau of Census, 2001a), and the corresponding spatial coverages of census tracts and blocks were generated from the 2000 Census TIGER line files (US Bureau of Census, 2001b). The centroid of the zip code of the hospital address was used to represent the hospital's location.

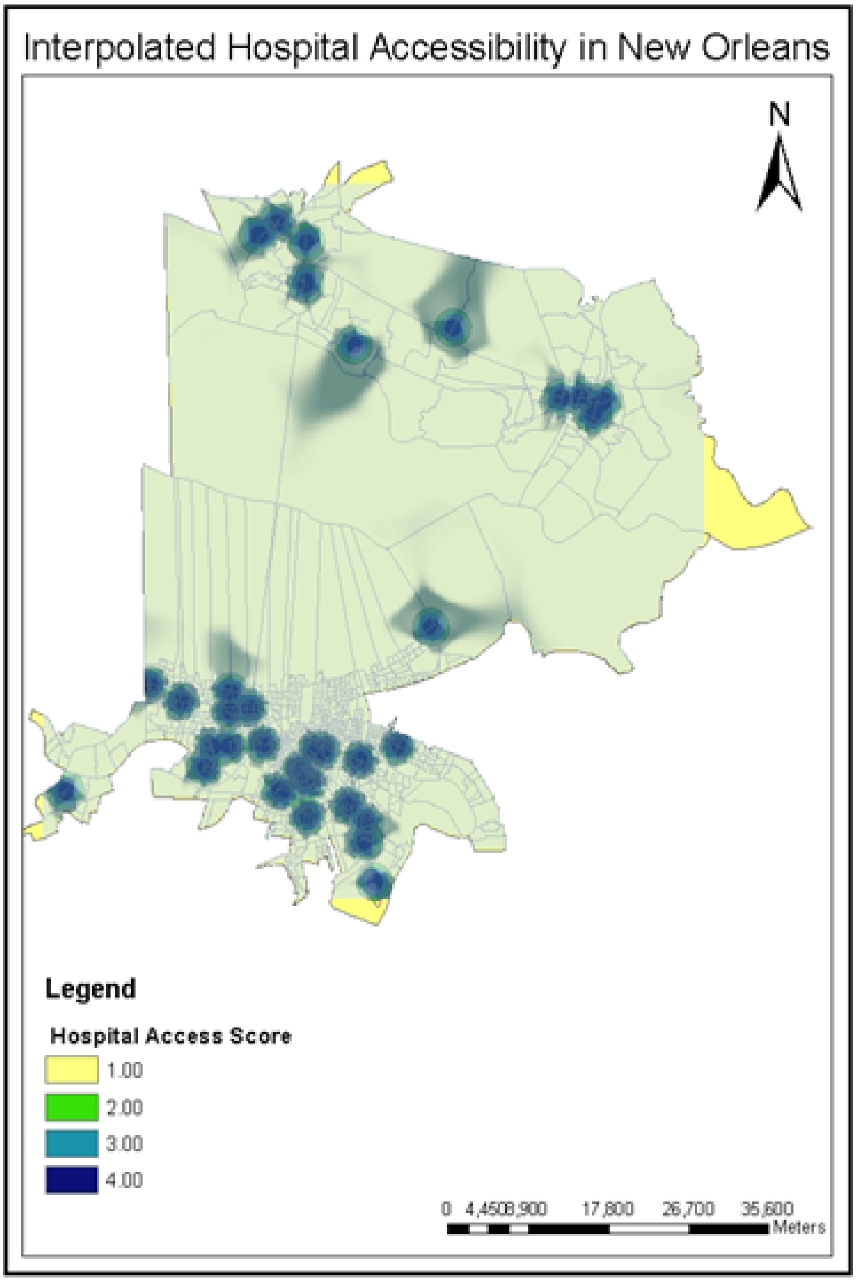

Figure 2: The Interpolated Hospital Accessibility in New Orleans Using the IDW Method

Table 1. Summary of the Basic Statistics

	Access Score	Total	Max.	Avg.	Min.	Standard Deviation
Total Population Density	1	728107.97	6246	1024.06	0	816.93
	2	158420.09	1877.68	397.04	0	358.19
	3	155994.14	5060.60	422.75	0	419.97
	4	154054.81	4642.25	566.38	0	586.97
White Population Density	1	393458.52	5702.40	553.39	0	678.31
	2	96378.58	1568.27	241.55	0	283.87
	3	90803.28	1259.39	246.08	0	269.04
	4	92914.62	2857.44	341.60	0	400.819
Black Population Density	1	295488.73	4202	415.60	0	548.58
	2	53184.81	1244.30	133.30	0	215.22
	3	56077.09	4465.60	151.97	0	328.02
	4	51487.37	4112.89	189.30	0	376.82
Asian Population Density	1	17642.15	2655	24.81	0	120.05
	2	2919.85	172.57	7.32	0	19.22
	3	2964.11	116.22	8.03	0	17.94
	4	3526.88	182.00	13.00	0	29.72
Hispanic Population Density	1	28317.72	442	39.83	0	54.00
	2	9129.67	382.64	22.88	0	43.45
	3	9401.61	1137.56	25.47	0	72.06
	4	8813.99	782.91	32.40	0	67.32

Circular Buffer Approach

The simplest and most common used GIS approach to create the catchment area from a hospital is to consider the Euclidean distance from the hospital. Concentric rings of 1000, 1500 and 2000 meters around the hospitals were created. To population within 1000 meters from any hospital(s) an access score of 4 was assigned, to population within 1000-1500 meters an access score of 3 was assigned, to population within 1500-2000 meters an access score of 2 was assigned and to population outside of 2000 meters an access score of 1 was assigned.

Figure 2 shows the interpolated local pattern of hospitals in the study area and the hospital accessibility scores in New Orleans using the Inverse Distance Weighted (IDW) method. We can notice that the hospitals are more concentrated in the south part of New Orleans and some of the hospitals are in the north and northeast. This reflects better accessibility in the south of New Orleans and lower accessibility in the suburban and rural areas. This is logical because it follows the population concentration in New Orleans.

Table 1 summarizes the basic statistics for the total population (White and three major ethnic minorities (Black, Asian and Hispanic)) with various accessibility scores. It can be seen that 60.85% of the total population suffer from poor accessibility with a very low score of 1 and that only almost 12.87% of them are served by high accessibility with a score of 4, whereas 13.24 % of the population are served by low accessibility with a score of 2. The remaining 13.04 % of the population are served by moderate accessibility with a score of 3.

Also, it can be seen that only 15.83% of the Hispanic, 13.79 % of the White, 13.04 % of the Asian and 11.29 % of the Black populations are served by the highest accessibility score of 4. And, 50.87% of the Hispanic,58.42 % of the White, 65.21 % of the Asian and 11.29 % of the Black populations are served by the lowest accessibility score of 1.

Table 2 summarizes the weighted averages of scores for the total population (White and the three major ethnic minorities (Black, Asian and Hispanic)). Clearly, it can be seen that the Hispanic population has the highest average access score of 1.98, then comes the White population with 1.83 average access score, then the Asians with 1.72 average access score and lastly the Blacks suffer from having the poorest accessibility score of 1.70.These results are consistent with the results from Table 1. Also, it is worth noticing that the White and the Hispanic scores are above the total population weighted average score which is 1.81, but the Asians and Blacks have scores below the weighted average score.

Table 2. Summary of the Average Scores

	Total	**Average Score**
White	673555	1.83
Black	456238	1.70
Asian	27053	1.72
Hispanic	55663	1.98
Total Population	1196577	1.81

Table 3 summarizes the average income within each accessibility score. It can be seen that the average income is almost the same within each accessibility score.

Table 3. Summary of the Average Income

Score	**Average Income**
1	37292.01
2	37501.41
3	37575.87
4	37293.16

Spatial Cluster Analysis

Spatial Cluster Analysis tools were used to examine the ethnic minorities and income patterns in New Orleans. These tools include statistics for global and local clustering. Basically, the tools detect unusual concentrations or non-randomness of events in space. In other words, the question to be addressed is whether the clustering of events is purely by chance or not. Global clustering is used to investigate whether there is clustering throughout the study area. Moran's *I* statistic was used as an indicator that spots global clustering; it spots whether nearby areas have similar or dissimilar overall attributes. Moran's *I* varies between -1 and 1. A value near 1 indicates positive spatial clustering; that is similar attributes are clustered, either high values near high values or low values near low values. A value of -1 indicates negative spatial clustering; that is non-similar attributes are clustered, either high values near low values or low values near high values. If Moran's *I* is zero or close to zero, it indicates a random pattern. Local clustering is important to identify cluster locations. General *G* statistic was used as an indicator that spots local clustering. General *G* varies between 0 and 2. Typically, values between 0 and 1 indicate positive spatial clustering, while values between 1 and 2 indicate negative spatial clustering, therefore General *G* is inversely related to Moran's *I*.

For both General *G* and Moran's *I*, the statistical test used is a standard normal *Z* test. Table 4 summarizes the values of General *G* and Moran's *I* and the corresponding Z-scores for the three ethnic minorities (Black, Asian and Hispanic). If the *Z*-score is greater than 1.96 (critical value), it is statistically significant at 95 percent confidence level, and if the *Z*-score is greater than 2.576 (critical value), it is statistically significant at 99 percent confidence level. A positive I_i means either a high value surrounded by high values (high-high) or a low value surrounded by low values (low-low). A negative I_i means either a low value surrounded by high values (low-high) or a high value surrounded by low values (high-low). It was found that the three minorities have positive I_i values of (0.22, 0.04 and 0.09) for (Black, Asian and Hispanic) minorities, respectively. These values imply that the three minorities tend to have similar cluster patterns (high-high) or (low-low). The corresponding *Z*-scores, 179.11, 33.84 and 79.58 for Black, Asian and Hispanic minorities, respectively, imply that the pattern is clustered with very high significance and there is less than 1 percent likelihood that this clustered pattern could be the result of random chance. Also, this result suggests that the spatial clustering pattern is the strongest in the Black minority.

Table 4. Summary of General *G* and Moran's *I* and the Corresponding Z-values

Black	Moran's *I*	Value	0.22
		Z-score	179.11
	General *G*	Value	0.00
		Z-score	22.37
Asian	Moran's *I*	Value	0.04
		Z-score	33.84
	General *G*	Value	0.00
		Z-score	1.35
Hispanic	Moran's *I*	Value	0.09
		Z-score	76.58
	General *G*	Value	0.00
		Z-score	5.34

The general *G* index detects whether high values or low values (not both) tend to cluster in the study area. A general *G* index of 0 value with 22.37 *Z*- score for Blacks imply that the case is a highs' cluster with high significance level with less than 1 percent likelihood that the clustering of high values could be the result of random chance. A general *G* index of 0 value and 1.35 Z- score for Asians imply that while there is some clustering, the pattern may be due to random chance and the confidence level is low. A general *G* index of 0 value and 5.34 Z- score for the Hispanic minority imply that the case is a highs' cluster with high significance level and there is less than 1 percent likelihood that the clustering of high values could be the result of random chance.

Table 5 summarizes the values of General *G* and Moran's *I* and the corresponding *Z*-values for the income in New Orleans. Moran's *I* value of 0.15 implies that the pattern is clustered with a high value surrounded by high values or a low value surrounded by low values. *Z*-score of 118.28 implies that the pattern is clustered with high significance and there is less than 1 percent likelihood that this clustered pattern could be the result of random chance. A general *G* value of 0 and -11.76 *Z*- score imply that the case is a lows' cluster with high significance level and there is less than 1 percent likelihood that the clustering could be the result of random chance.

Table 5. Summary of General *G* and Moran's *I* and the Corresponding Z-values

Income	Moran's *I*	Value	0.15
		Z-score	118.28
	General *G*	Value	0.00
		Z-score	-11.76

SUMMARY AND CONCLUSIONS

This paper has presented the results of a case study to analyze hospital accessibility in New Orleans Metropolitan Area by using population and hospital disaggregated data at a more detailed geographic resolution. The paper's main contribution is that the method applied to measuring hospital accessibility using smaller geographic units (that is; population at census tract level and hospitals at the zip code level), and therefore more details of accessibility variations can be revealed.

This research used a simple circular buffer approach in GIS to create catchment areas from hospitals by creating concentric rings of 1000, 1500 and 2000 meters around the hospitals. Different scores ranging from 1 to 4 were assigned to each concentric ring with 4 being the highest/closest score and 1 being the lowest/furthest one. Then, the paper examined the possible inequality among disadvantaged population subgroups (low income and minority residents) using Spatial Cluster Analysis (SCA) tools of hospital accessibility. Among the general findings, it was found that almost 61% of the total population in New Orleans suffer from poor accessibility with very low score of 1 and only almost 13% of them are served by high accessibility with a score of 4. Also, it was found that the Hispanic minority has the highest average access score of 1.98, then comes the White minority with 1.83 average access score, then the Asians with 1.72 average access score and lastly the Blacks suffer from having the poorest accessibility score of 1.70. Finally, it was found that income tends to have a lows' cluster with high significance level and less than 1 percent likelihood that the clustering of low values could be the result of random chance.

Recommendations and Suggested Future Work

The following recommendations are made to help improve hospital accessibility in New Orleans:

1- Increase allocations to already existing hospitals and healthcare centers.
2- Encourage private sector and physicians to provide more affordable medication.
3- Government should support financially the development of new healthcare centers and hospitals across the parish.

The research can be further improved by differentiating population with or without personal vehicles; that is the disadvantaged population who must depend on public transit. For those without vehicles and having to depend on public transit, their accessibility to healthcare is diminished to a great degree. Giuliano (2005) defined disadvantaged populations as "*those who are unable or unwilling to drive, or who do not have access to a private vehicle*". Also, further research and investigation are required to evaluate the impact of traveling speed on hospital accessibility.

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